We claim:

1. A method for locating/sizing contaminants on a bare, highly polished, and planar surface of a dielectric or semiconductor material, comprising the steps of:

focusing a coherent beam of diffraction limited monochromatic P-polarized light from a solid-state (no gas plasma involved) light source and directed specifically at Brewster's angle (principal angle) to form a quasi-elliptical illuminated spot on the material surface which specularly reflects a circular minimal power beam from the surface of the material the cross-section of which has a dark (no-light) central band and two outer low light lobes;

causing a contaminant on the material surface to pass multiple times through the quasi-elliptical illuminated spot incident on the material surface so that the contaminant, on each pass through the illuminated spot, scatters the light in a quasi-hemispherical pattern; and

disposing a high numerical aperture light collector, focused on the center of the quasi-elliptical illuminated spot, above and in close proximity to the material surface so as to redirect essentially all the light scattered (with effectively no secondary redirection) from the contaminant to a detector capable of converting the light collected to an electrical signal proportional to the light intensity.

2. The method of claim 1, wherein the high numerical aperture light collector, the detector, and all optics are optimized for the wavelength of the incident monochromatic light beam.

3. The method of claim 1, further including the step of disposing the light collector relative to the material surface so that effectively no reflected light, resulting from the incidence of the beam on the material surface is captured by the light collector.

4. The method of claim 1, wherein the high numerical aperture light collector is a highly elongate ellipsoidal reflector with an internal reflecting surface and an equivalent numerical aperture of ≥ 0.85.

5. The method of claim 4, wherein the ellipsoidal reflector includes a major to minor axes ratio of at least 4.5:1, a reflective inner surface that extends 90-95% of the distance

between the two focal points, and an ellipsoid minor diameter to entrance aperture diameter ratio of $\geq 3.1:1$.

6. The method of claim 4, further including disposing the ellipsoidal reflector relative to the material surface so that a line between focal points of the reflector is normal to the material surface.

7. The method of claim 4, further including positioning the ellipsoidal reflector relative to the incident P-polarized light beam and the specularly reflected light beam so that the beams pass between a bottom surface of the ellipsoidal reflector and the material surface with no interference.

8. The method of claim 4, wherein the ellipsoidal reflector includes first and second notches formed into the bottom surface of the ellipsoidal reflector, the first notch adapted to pass with no interference the incident P-polarized light beam there-through and the second notch adapted to pass with no interference the light beam specularly reflected from the material surface there-through.

9. The method of claim 1, wherein the high numerical aperture light collector is a refractive lens system with a numerical aperture of ≥ 0.7.

10. The method of claim 9, wherein the refractive lens system is an infinity-corrected system with a numerical aperture of ≥ 0.7.

11. The method of claim 10, wherein the refractive lens system has a length to diameter ratio of $\geq 2.75:1$.

12. The method of claim 9, further including disposing the refractive lens system relative to the material surface so that its optical axis is normal to the wafer surface.

13. The method of claim 9, further including positioning the refractive lens system relative to the incident P-polarized light beam and the specularly reflected light beam such that

the beams pass between a bottom surface of the refractive lens system and the material surface with no interference.

14. The method of claim 9, wherein the refractive lens system includes first and second notches formed into the bottom surface of the refractive lens system, the first notch adapted to pass with no interference the P-polarized light beam there-through and the second notch adapted to pass with no interference the light specularly reflected from the material surface there-through.

15. The method of claim 1 further including disposing a beam dump to trap and fully dissipate the entire two-lobe beam that is specularly reflected from the material surface.

16. The method of claim 15, the beam dump including a low numerical aperture light collector and detector combination, the method further including collecting substantially all of the two lobe beam specularly reflected from the material surface, allowing the collected beam to be viewed on a remote display, and fully dissipating the collected beam.

17. The method of claim 16, wherein the detector includes a CCD camera, a linear (1D) light position detector, or a quadrant (2D) light position detector.

18. The method of claim 1, further including the steps of: grouping the light source, the high numerical aperture scattered light collector, and the detector together into an instrument group, mounting the instrument group on an arm, and moving the instrument group in unison within a plane above and parallel to the material surface.

19. The method of claim 18, further including rotating the material surface on a base about an axis of rotation perpendicular to the material surface and then simultaneously moving the instrument group within a plane that is above and parallel to the material surface from outside the periphery of the material surface to at least the axis of rotation of the material surface so that the quasi-elliptical spot can illuminate any desired area of the material surface.

20. The method of claim 19, wherein the instrument group is mounted on the free end of a pivot arm so that the quasi-elliptical spot moves in an arc to illuminate a desired area on

the material surface in a spiral pattern due to the rotation of the material surface and the arc path of the instrument group arm above the material surface.

21. The method of claim 19, further including mounting the instrument group on a free end of non-pivoting arm and moving the quasi-elliptical spot in a straight line to illuminate a desired area on the material surface in a spiral pattern as the material surface is rotated under the instrument group arm.

22. The method of claim 18, further including disposing and controlling two or more instrument groups separately on an arm to reduce the scan time by a factor of two or more, each instrument group including a light source and a collector/detector assembly, and illuminating a same side of a contaminant with the light source of each instrument group.

23. The method of claim 22, further including disposing the instrument groups apart so that the illuminated spot from each group follows a portion of a continuous arc path on the material surface and the plane of each incident light beam and its normal to the material surface are tangent to the arc path.

24. The method of claim 18, further including arranging and controlling two or more instrument groups separately on an arm so as to illuminate each contaminant from two or more sides; each instrument group comprised of a light source and a collector/detector assembly and with any two light sources illuminating generally opposite sides of a contaminant.

25. The method of claim 24, further including disposing the instrument groups apart so that the illuminated spot from each group follows the same arc path and arc length on the material surface and the plane of each incident light beam and its normal to the material surface is tangent to the arc path.

26. The method of claim 18, further including moving the material surface in a straight line and simultaneously moving the instrument group(s) as a single unit in a straight line perpendicular to the straight line motion of the material surface, from outside the periphery of the material piece so the quasi-elliptical spot(s) can illuminate any desired area of the material surface in a rectangular two dimensional pattern.

27. The method of claim 18 further including moving the instrument group and the material surface so as to position the light collector and incident illuminated spot over a desired contaminant and statically capturing a scattered light pattern from the desired contaminant on a remote display.

28. The method of claim 18, further including disposing a beam dump to trap and fully dissipate the entire two-lobe beam that is specularly reflected from the material surface.

29. The method of claim 1, further including the step of disposing a scattered ray dump about the sensitive face of the detector and the exit aperture of the light collector.

30. The method of claim 1, wherein the contaminant scattered light collector/light-dump/detector assembly is configured so that the scattered light rays (photons) pass only one time through the assembly.

31. The method of claim 1, wherein a detector is disposed to provide an electrical signal from a datum on the material surface.

32. *The method of claim 1, further including associating time and the detector* signals with a fixed location on the material surface.

33. The method of claim 1, further including storing, processing, and comparing the multiple electrical signals from the detector created by each contaminant to a calibration curve relating processed signal magnitude to that from standardized (size, shape, and material) contaminants and to a fixed datum location on the material surface.

34. An apparatus for locating/sizing contaminants on a bare, highly polished, and planar surface of a dielectric or semiconductor material comprising:

means for directing a focused coherent diffraction limited beam of monochromatic P-polarized light from a solid-state (no gas plasma involved) light source and specifically disposed at Brewster's angle (principal angle) to form a quasi-elliptical illuminated spot on the material surface that specularly reflects a circular minimal power beam from the material surface the cross-section of which has a dark (no-light) central band and two outer low light lobes; the

center of said illuminated spot coincident with the focal point of the beam on the beam optical axis and on the material surface;

a high numerical aperture light collector disposed above and in close proximity with the material surface and focused on the center of the quasi-elliptical illuminated spot on the material surface to maximize capture of quasi-hemispherically scattered light from a contaminant illuminated by the light beam incident on the material surface; and

a detector disposed near the exit aperture of the light collector opposite the material surface for generating a signal indicative of the intensity of the scattered light captured by and redirected through the light collector to the detector.

35. The apparatus of claim 34, wherein the high numerical aperture light collector, the detector, and all optics are optimized for the wavelength of the incident monochromatic light beam.

36. The apparatus of claim 34, further including the step of disposing the light collector relative to the material surface so that effectively no reflected light, resulting from the incidence of the beam on the material surface, is captured by the light collector.

37. The apparatus of claim 34, wherein the high numerical aperture light collector is a highly elongate ellipsoidal reflector with an internal reflecting surface and an equivalent numerical aperture of ≥ 0.85.

38. The apparatus of claim 37, wherein the ellipsoidal reflector includes a major to minor axes ratio of at least 4.5:1, a reflective inner surface that extends 90-95% of the distance between the two focal points, and an ellipsoid minor diameter to entrance aperture diameter ratio of $\geq 3.1:1$.

39. The apparatus of claim 37, wherein the ellipsoidal reflector is disposed relative to the material surface so that a line between focal points of the reflector is normal to the material surface.

40. The apparatus of claim 37, wherein the ellipsoidal reflector is positioned relative to the incident P-polarized light beam and the specularly reflected light beam so that the beams

pass between a bottom surface of the ellipsoidal reflector and the material surface with no interference.

41. The apparatus of claim 37, wherein the ellipsoidal reflector includes first and second notches formed into the bottom surface of the ellipsoidal reflector, the first notch adapted to pass with no interference the incident P-polarized light beam there-through and the second notch adapted to pass with no interference the light beam specularly reflected from the material surface there-through.

42. The apparatus of claim 34, wherein the high numerical aperture light collector is a refractive lens system with a numerical aperture of ≥ 0.7.

43. The apparatus of claim 42, wherein the refractive lens system is an infinity-corrected system with a numerical aperture of ≥ 0.7.

44. The apparatus of claim 43, wherein the refractive lens system has a length to diameter ratio of $\geq 2.75:1$.

45. The apparatus of claim 42, wherein the refractive lens system is disposed relative to the material surface so that its optical axis is normal to the wafer surface.

46. The apparatus of claim 42, wherein the refractive lens system is positioned relative to the incident P-polarized light beam and the specularly reflected light beam such that the beams pass between a bottom surface of the refractive lens system and the material surface with no interference.

47. The apparatus of claim 42, wherein the refractive lens system includes first and second notches formed into the bottom surface of the refractive lens system, the first notch adapted to pass with no interference the P-polarized light beam there-through and the second notch adapted to pass with no interference the light specularly reflected from the material surface there-through.

48. The apparatus of claim 34 further including a beam dump arranged and configured to trap and fully dissipate the entire two-lobe beam that is specularly reflected from the material surface.

49. The apparatus of claim 48, wherein the beam dump includes a low numerical aperture light collector and detector combination to collect all of the two lobe beam specularly reflected from the material surface, allow it to be viewed on a remote display, and to fully dissipate it.

50. The apparatus of claim 49, wherein the detector is a CCD camera, a linear (1D) light position detector, or a quadrant (2D) light position detector.

51. The apparatus of claim 34, wherein the light source, the high numerical aperture scattered light collector, and the detector together are grouped into an instrument group, mounted on an arm, and arranged and configured for movement in unison within a plane above and parallel to the material surface.

52. The apparatus of claim 51, wherein the material surface is arranged and configured for rotation on a base about an axis of rotation perpendicular to the material surface, said instrument group moveable within a plane that is above and parallel to the material surface from outside the periphery of the material surface to at least the axis of rotation of the material surface so that the quasi-elliptical spot can illuminate any desired area of the material surface.

53. The apparatus of claim 52, wherein the instrument group is mounted on the free end of a pivot arm so that the quasi-elliptical spot moves in an arc to illuminate a desired area on the material surface in a spiral pattern due to the rotation of the material surface and the arc path of the instrument group arm above the material surface.

54. The apparatus of claim 53, further including an ultra-low vibration and speed-controlled electric motor coupled to the pivot arm.

55. The apparatus of claim 52, wherein the instrument group is mounted on the free end of non-pivoting arm so that the quasi-elliptical spot is capable of moving in a straight line to illuminate a desired area on the material surface in a spiral pattern due to the rotation of the

material surface and the straight line path of the instrument group arm above the material surface.

56. The apparatus of claim 55, further including an ultra-low vibration and speed-controlled electric motor driven linear stage coupled to the non-pivoting arm and arranged and configured to move the instrument group non-pivoting arm in a straight line.

57. The apparatus of claim 52, further including an ultra-low vibration and speed-controlled electric motor arranged and configured to move the instrument group non-pivoting arm in a straight line, and further including a vacuum chuck and non-contact vacuum line coupling, wherein the vacuum chuck dimensions allow a SEMI (Semiconductor Equipment and Materials Industry) standard robot end-effector to place, center, and remove the material piece.

58. The apparatus of claim 51, further including disposing and controlling two or more instrument groups separately on an arm to reduce the scan time by two or more; each instrument group comprised of a light source and a collector/detector assembly and with the light sources illuminating generally the same side of a contaminant.

59. The apparatus of claim 58, further including disposing the instrument groups apart so that the illuminated spot from each group follows a portion of a continuous arc path on the material surface and the plane of each incident light beam and its normal to the material surface is tangent to the arc path.

60. The apparatus of claim 51, further including arranging and controlling two or more instrument groups separately on an arm so as to illuminate each contaminant from two or more sides; each instrument group comprised of a light source and a collector/detector assembly and with any two light sources illuminating generally opposite sides of a contaminant.

61. The apparatus of claim 60, further including disposing the instrument groups apart so that the illuminated spot from each group follows the same arc path and arc length on the material surface and the plane of each incident light beam and its normal to the material surface is tangent to the arc path.

62. The apparatus of claim 51, the material surface being moveable in a straight line and the instrument group simultaneously moveable as a single unit in a straight line perpendicular to the straight line motion of the material surface from outside the periphery of the material piece so the quasi-elliptical spot(s) can illuminate any desired area of the material surface in a rectangular two dimensional pattern.

63. The apparatus of claim 62 further including ultra-low vibration and speed-controlled electric motor drive linear stages for moving the instrument group arm in a straight line relative to the material surface.

64. The apparatus of claim 51 further including a capability to jog the instrument group(s) as a single unit and the movement of the material surface so as to position a particular light collector and incident illuminated spot over any desired contaminant and statically capture its scattered light pattern on a remote display.

65. The apparatus of claim 51, further including a beam dump as part of the instrument group that is arranged and configured to trap and fully dissipate the entire two-lobe beam that is specularly reflected from the material surface.

66. The apparatus of claim 34, wherein all of the components are packaged in an air-tight sealable container with a sealable door to allow appropriate insertion of a material piece into the container and that is sized to fit a SEMI (Semiconductor Equipment and Materials Institute) standard FOUP loadport for 300 mm diameter wafers.

67. The apparatus of claim 66, wherein the container is filled with a gas other than ambient air.

68. The apparatus of claim 66, wherein the container is evacuated.

69. The apparatus of claim 66, the container including strategically placed baffles and laminar flow surface shapes for suppressing gas turbulence inside the container caused by spinning material surface drag.

70. The apparatus of claim 66, further including means for suppressing internal and external vibrations that could distort an output signal from the scattered light detector.

71. The apparatus of claim 34, further including means for tracking the material surface to effectively eliminate distortion of the output signal from the scattered light detector due to material surface dimensional tolerances (warp, waviness, etc).

72. The apparatus of claim 34 wherein the light source is a coherent and monochromatic laser that (1) is small (≤ [5 in. L x 3 in. W x 1.25 in. H]), (2) is light-weight (≤ 0.5 lb.), (3) is solid-state (no gas plasma involved), (4) is thermoelectrically cooled, (5) operates only in a continuous wave (CW) TEMoo mode, (6) has a mode quality $M^2 \leq 1.1$, (7) has a capability to adjust beam power from its maximum through a computer, (8) has a beam polarization ratio ≥100:1, (9) can be focused (with appropriate optics) to a diffraction limited spot with a circular cross-section, a Gaussian irradiance profile centered about the optical axis and a diameter in the range of 8 to 12 microns, and (10) can be operated at full power for at least 10,000 hours.

73. The apparatus of claim 72, wherein the laser operates at a single wavelength within the ranges ≤470 nm or ≥700 nm.

74. The apparatus of claim 72, wherein the laser operates at a single wavelength within the ranges > 470 nm and < 700 nm.

75. The apparatus of claim 34, further including a scattered ray dump disposed about a sensitive face of the detector and the exit aperture of the light collector.

76. The apparatus of claim 34, further including a CCD camera mounted on a linear or rotary stage with the scattered light sensor where both can move together between first and second positions where in a first position the scattered light detector is disposed over the scattered light collector and in a second position where the CCD camera is disposed over the scattered light collector to allow visual inspection of the scattered light signature from a particular contaminant on a remote monitor.

77. The apparatus of claim 34, wherein the contaminant scattered light collector/light-dump/detector assembly is configured so that the scattered light rays (photons) pass only one time through the assembly.

78. The apparatus of claim 34, wherein a detector is disposed to provide an electrical signal from a datum on the material surface.

79. The apparatus of claim 34, further including means for associating time and the detector signals with a fixed location on the material surface.

80. The apparatus of claim 34, further including means for storing, processing, and comparing the multiple electrical signals from the detector created by each contaminant to a calibration curve relating processed signal magnitude to that from standardized (size, shape, and material) contaminants and to a fixed datum location on the material surface.

81. The apparatus of claim 34, wherein the light source/optics, the scattered light collector/detector subassembly, and a optional reflected light beam dump are disposed on a pivot or linear motion arm/motor-drive subsystem, the vacuum chuck subsystem with its integrated motion-drive/vacuum-coupling subsystems, a material surface datum detector, and support electronics are integrated into a first portable module that is the approximate size of a SEMI standard 300 mm FOUP that can lock to a SEMI standard load-port or other through-the-wall clean-room interface and that is connected via a portable umbilical to a second portable module containing self-contained power, vacuum, data capture/processing/control/data-display, and docking/undocking subsystems for the first module.

82. The apparatus of claim 81 wherein the first and second portable modules are integrated onto a SEMI standard load-port panel, the self contained power/vacuum supplies are obtained from sources external to the overall assembly, and the umbilical and docking/undocking of the first/second portable modules are eliminated.

83. The apparatus of claim 82 wherein the data capture/processing/control/data-display subsystems are located remote from the overall assembly in a central facility control center and connected via hard wire or wireless means.